Chapter 2
Cell: The Building Block of Life

Redeveloped Edition *| Class 9 Science | IESC Series*

Original NCERT content reimagined with everyday Indian-life examples, redeveloped worked problems, and interdisciplinary insight — same rigour, re-anchored in 2026.

Opening Wonder

Last night, someone in your house probably did something quietly miraculous. They took a pot of warm milk, stirred in a spoonful of yesterday's curd (dahi), and left it covered on the kitchen counter overnight. By morning, the entire pot had transformed — thick, tangy, fully set curd, ready for your breakfast thali.

Nothing was added except that one spoonful of old curd. So where did all the *new* curd come from?

The answer is billions of ***Lactobacillus*** bacteria — each one a single, complete, living cell — multiplying every twenty minutes or so overnight, converting milk sugar into lactic acid and curdling the milk protein along the way. The handful of bacteria you started with became billions by sunrise. And every single one of those billions is a **cell**, and every cell came from a cell that existed before it.

This is where our chapter begins: at the smallest unit that can truly be called 'alive.'

It is widely accepted among scientists that life itself first originated in water — though perhaps not in the vast oceans. Many researchers believe life may have begun in small water pools with rapidly changing conditions, such as hot springs. In India, the hot springs of Puga Valley in Ladakh stay close to the boiling point of water even through Ladakh's freezing winters — conditions thought to resemble Earth's environment roughly 3.5 billion years ago. The organisms that thrive there today are unicellular, heat-loving bacteria called **thermophiles**.

Researchers at the Birbal Sahni Institute of Palaeosciences, Lucknow, studying these hot springs found that calcium carbonate deposits form rapidly around them — deposits that may have shielded early organic molecules from harmful radiation, and may even have helped shape the very first protective membrane: the barrier that defines a cell.

Every living organism, from the ***Lactobacillus*** in your curd to the person reading this sentence, is built from cells. Some organisms — bacteria, yeast — are **unicellular**, a single cell doing everything a living thing needs to do. Others — plants, fish, birds, you — are **multicellular**, built from millions (or trillions) of cells working as a team. Groups of similar cells performing the same job form **tissues**; tissues organise into **organs**; organs cooperate as **organ systems** — your nasal passages, nasal cavity, trachea, and lungs, for instance, together form your respiratory system.

Yet no matter how complex the body built around it becomes, the cell never stops being the basic unit of structure and function. That raises real questions worth sitting with: What is actually inside a cell that lets it do so much? How does

a cell come into being? How does it multiply? And how have scientists managed to study something far too small for the human eye to ever see directly?

Think It Over

- Where does a cell come from?
- How have technological interventions (like microscopes) facilitated new knowledge about a world beyond the naked eye?
- How is the cell the structural and functional unit of life?
- How does a cell multiply?

2.1 How to Study Cells?

Try this: take a pen and mark two dots close together on paper. Hold the page at arm's length — about 25 cm, the 'near point' at which the human eye focuses comfortably — and slowly bring the dots closer. At some point, no matter how sharp your eyesight, the two dots merge into what looks like a single blurred point.

That gap — about **0.1 mm** — is called the **limit of resolution of the human eye**: the smallest separation between two points that your eye can still perceive as *two* points rather than one. A typical cell is far smaller than this. This is exactly why a cell is invisible to the unaided eye, and why humanity needed a technological breakthrough before anyone could even suspect that living things are built from tiny, repeating units.

Everyday Connection: Your Phone's Macro Mode vs a Real Microscope

Most 2026-era smartphones ship with a 'macro mode' that focuses on something just a few centimetres away and digitally zooms in 5–10 times. Point it at a coin or a flower and it looks impressively close-up. But even the sharpest phone macro shot cannot get anywhere near the 100–1500X magnification of a school light microscope, let alone the far higher magnification of an electron microscope used to photograph a virus. A phone camera bends and focuses visible light using a small glass lens — conceptually the same idea Robert Hooke used in 1665 — but a research-grade microscope pushes that idea very much further, using combinations of lenses and, eventually, beams of electrons instead of light.

You have already learnt about the convex lens in Grade 8. A convex lens, or a combination of lenses — an **objective lens** and an **eyepiece** — is used to magnify an object and make it appear larger.

Robert Hooke and the First 'Cells'

In 1665, the English scientist **Robert Hooke** built his own microscope, capable of roughly 200–300X magnification. Examining a wafer-thin slice of cork under it, he noticed rows of small, empty, box-like compartments — and, because they reminded him of the tiny rooms in a monastery, he named them **cells**. It's worth pausing on that word choice: in ordinary English, 'cell' still means a small bare room — a prison cell, a monk's cell. Hooke's naming is exactly why biology

borrowed that everyday word and gave it an entirely new, precise meaning: *the fundamental unit of all life.*

Light and Electron Microscopes

In school laboratories, **light microscopes** are used to observe objects, using different objective lenses (10X, 40X, and so on) to achieve better magnification and resolution under visible light. Under the microscope, you see a magnified *image* of an object — but can you estimate the object's actual size from that image? (We'll do exactly this in the activity below.)

Apart from light microscopes, scientists also use powerful **electron microscopes** that reveal the fine details of a cell's structure. These instruments use a beam of electrons instead of light to produce highly magnified images, allowing us to see cell structures at the **nanometre** scale (1 nanometre = one-billionth of a metre) with remarkable clarity. Over the years, scientists have improved microscopes by improving three key features — **resolution** (a measure of clarity), **contrast** (the difference in brightness between different parts of an object), and **magnification**. Together, these improvements have turned the microscope into one of biology's most powerful tools — sharp enough, for instance, to photograph the tiny pores called stomata on the lower surface of a Colocasia (arbi) leaf under a Scanning Electron Microscope.

Activity 2.1 — Redeveloped: Estimating the Size of an Onion Cell

Original book version: Use a transparent ruler to measure the microscope's field-of-view diameter, then count cells across an onion peel slide to estimate the size of one cell.

Everyday Version: Your school science teacher hands you a glass slide with a wafer-thin peel from a kitchen onion — the same kind sitting on your sabzi cutting board — mounted under a light microscope. Your task: using nothing but a plastic ruler and careful counting, estimate the actual size of a single onion cell.

Step 1: Place a transparent millimetre ruler on the microscope stage, focus on it, and measure the diameter of the bright circular field of view you see through the eyepiece. Suppose it measures **5 mm**.

Step 2: Convert to micrometres (1 mm = 1000 µm), so 5 mm = **5000 µm**.

Step 3: Remove the ruler, mount the onion peel slide instead, and count how many cells line up across that same diameter in a single straight line. Suppose you count **25 cells**.

Step 4 — the formula:

Estimated size of a cell = (Diameter of visible field in µm) ÷ (Number of cells along the diameter)

= 5000 µm ÷ 25 = **200 µm**

Sanity check with an everyday scale: a single human hair is roughly 70–100 µm thick. So one onion cell, at 200 µm, is about two to three hair-widths across — small, but not unimaginably so.

Push it further: if both your eyepiece and objective lens are rated 10X, total magnification = 10 × 10 = **100X**. A real 200 µm cell, magnified 100 times, appears to your eye as if it were about 2 cm wide — bigger than a one-rupee coin.

 Creative Spark: A microscope doesn't make the actual cell bigger — it only makes the *image* of the cell bigger. Why does this distinction matter when a scientist reports the 'real size' of something they have only ever seen through a lens?

Ready to Go Beyond: Life Forms Too Small to Be Cells

Not everything infectious is a cell. **Viruses, viroids, and prions** are acellular (they have no cell structure at all) and are too small to be seen under a light microscope. A virus is genetic material wrapped in a protein coat. A viroid is bare genetic material with no protein coat at all. A prion isn't even made of genetic material — it is a misfolded protein that can cause other, normal proteins to misfold too. All three depend entirely on invading a real, living cell in order to multiply.

2.2 Structure of a Cell

You have learnt that cells are organised into specialised tissues and organs, and together perform specific functions. For cells to function as units, they must be able to interact with one another and with their surroundings. These interactions happen at the cell's boundary, where substances move between the cell and its external environment. Even single-celled organisms exchange materials and respond to their environment through this boundary — the **cell membrane**.

2.2.1 Cell Membrane — The Universal Feature of a Cell

The **cell membrane** is a thin boundary that surrounds a cell and protects its contents. It is also called the **plasma membrane**, and it defines the individuality of a cell. Crucially, the cell membrane is **selectively permeable** — it allows some substances to pass through while blocking others.

Activity 2.2 — Redeveloped: Osmosis with Kitchen Ingredients

Original book version: Two equal potato pieces are placed in plain water and in a 20% salt/sugar solution; their weight change is measured after an hour.

Everyday Version: Ask an adult for two similar-sized chunks of peeled potato — or think of raw mango (kairi) slices, exactly like a street vendor's, which 'sweat' water within minutes of being sprinkled with namak-mirch.

- Cut two roughly equal pieces of potato and weigh each on a kitchen scale.
- Drop one piece into Beaker A with plain water.
- Drop the other into Beaker B with a 20% salt or sugar solution (roughly two heaped tablespoons dissolved in a small glass of water — close enough for a first estimate).
- Leave both undisturbed for about an hour, then re-weigh both pieces.

What actually happens: the potato in plain water (Beaker A) **gains** weight — it swells. The potato in the concentrated solution (Beaker B) **loses** weight — it shrinks.

Why: the cell membrane lets water molecules cross freely but blocks larger sugar or salt molecules. Water always moves from a region of *more water, less*

solute (a dilute solution) toward a region of *less water, more solute* (a concentrated solution), until concentrations on both sides equalise. This one-way traffic of water across a selectively permeable membrane is called **osmosis** — and it is exactly why kairi releases water the moment you salt it: the salt outside pulls water out of every one of the mango's cells.

Diffusion is the net movement of particles from a region of higher concentration to one of lower concentration — this occurs even without a membrane present, driven simply by a **concentration gradient**. **Osmosis** is a special case: the diffusion of *water* specifically, across a *selectively permeable membrane*. In plants, water from the soil enters root cells precisely by this process of osmosis.

What happens when a cell is placed in solutions of different concentrations? There are three possibilities:

Comparison	Term	What happens to the cell
Solute concentration outside = solute concentration inside	**Isotonic solution**	No net movement of water; cell size stays the same
Solute concentration outside < solute concentration inside	**Hypotonic solution**	Water moves *into* the cell; cell swells
Solute concentration outside > solute concentration inside	**Hypertonic solution**	Water moves *out of* the cell; cell shrinks

Structurally, the cell membrane is extremely thin — about 7 to 10 nanometres (nm) thick — and is made up of **lipids** (fats) and **proteins**. Its structure is explained by the **fluid-mosaic model**:

- The membrane has a **lipid bilayer** — two layers of special fat molecules, with water-attracting heads facing outward and water-repelling tails facing inward — with proteins embedded in it.
- The molecules can move sideways, flip, and rotate within the membrane — hence it is described as **fluid**.
- Proteins in the membrane act like **gatekeepers**, helping specific substances pass through.
- Because the molecules are arranged like tiles in a mosaic, the model is called the **'mosaic'** model.

Everyday Connection: Gatekeeper Proteins and UPI QR Codes

A membrane protein doesn't block everything or let everything through — it recognises specific molecules by shape, the way a UPI payment scanner only accepts a validly formatted QR code and rejects anything else pointed at it. Selectivity, not brute-force blocking, is the design principle behind both.

2.2.2 Cell Wall — The Outer Covering of Cells

In general, plants cannot move from place to place, so they need a rigid structure to withstand environmental stresses like wind and rain. Cells of plants, fungi, and bacteria therefore have an additional covering outside the cell membrane, called the **cell wall**. The cell wall also helps leaves and flowers stay firm and keeps plants upright. Although rigid, the cell wall is permeable — water

and dissolved minerals can pass through it, which, combined with the selective permeability of the cell membrane, helps plant roots absorb water and nutrients from the soil.

Activity 2.3 — Redeveloped: Onion Peel vs Cheek Cells

Original book version: Prepare stained slides of onion/Rhoeo leaf peel and human cheek cells; compare their shapes under a microscope; repeat after placing both in 20% sugar solution.

Everyday Version: Prepare a temporary slide of a thin peel from an onion leaf (or a Rhoeo/Cradle-lily leaf) stained with safranin. Separately, gently scrape the inner side of your cheek with a cotton swab or the blunt end of a toothpick, spread the cells on a clean slide, add a drop of water and a few drops of methylene blue stain, and add a coverslip. Observe both slides under a microscope.

What you'll see: onion peel (or Rhoeo) cells are box-shaped and regularly arranged, while cheek cells are irregularly arranged and lack any fixed shape.

Now repeat with fresh slides of both, this time adding 20% sugar solution and observing after half an hour. You'll notice the **outer boundary of the plant cells stays exactly the same size**, even as their inner contents shrink — the gap between the outer wall and the shrunken inner cell becomes visible. The cheek cells, with no rigid wall to hold their outline, simply shrink all over.

Everyday Connection: The Cheek-Swab DNA Test

That same loose, irregular arrangement of cheek cells — easy to scrape off precisely because they have no rigid wall holding them in a fixed pattern — is exactly why a cotton-swab cheek scrape is the standard first step in real-world DNA testing kits, from ancestry tests to forensic identification. The biology-class activity and the forensic lab procedure are, quite literally, the same technique.

When a Rhoeo leaf or onion peel is placed in a concentrated sugar solution, the plant cells lose water through osmosis. However, they do **not** shrink in overall size, because the rigid cell wall holds its shape — only the inner cell membrane pulls away from the wall as its contents shrink. This shows that the cell wall helps plant cells stay firm in their original shape. Animal cells, such as cheek cells, have no cell wall — so without that rigid scaffold, they lose water and shrink all over. This flexibility, in turn, is exactly what supports movement in animal tissues; a cell wall would make muscle contraction or amoeboid movement impossible.

The plant cell wall is made primarily of **cellulose**, a carbohydrate formed from many linked glucose units. Cellulose in our diet acts as roughage, aiding digestion. Fungi and bacteria also have a cell wall, for the same reasons of protection and structural support.

2.3 The Cell Interior — A Coordinated Working System

You have learnt that most cells have three basic parts:

- a selectively permeable **plasma membrane**,

- a semi-fluid, jelly-like substance called the **cytoplasm**, and
- a prominent **nucleus**.

In addition to the nucleus, the cytoplasm contains several sub-cellular components called **organelles**, along with other substances — most of which are only visible with an electron microscope.

Activity 2.4 — Redeveloped: Comparing Bacterial, Plant, and Animal Cells

Everyday Version: Imagine three ID cards — one for a bacterial cell (say, the ***Lactobacillus*** in your curd), one for a plant cell (say, from the spinach in your palak paneer), and one for an animal cell (say, one of your own cheek cells). For each, check off which structures are present.

Table 2.1: Comparison of different kinds of cells based on their structure

Cell structure	Bacterial cell	Plant cell	Animal cell
Cell membrane	Present	Present	Present
Cell wall	Present	Present	Absent
Cytoplasm	Present	Present	Present
Well-defined nucleus	Absent	Present	Present
Nucleoid (primitive nucleus)	Present	Absent	Absent
Membrane-bound organelles	Absent	Present	Present

A bacterial cell lacks a well-defined nucleus and membrane-bound organelles (organelles surrounded by their own membranes). Such cells are called **prokaryotic** cells. In contrast, plant and animal cells have a well-defined nucleus and several membrane-bound organelles — these are called **eukaryotic** cells.

Table 2.2: Comparison between prokaryotic and eukaryotic cells

Characteristic	Prokaryotic cell	Eukaryotic cell
Primitive nucleus (nucleoid)	Present	Absent
Diameter of a typical cell	1 to 10 µm	10 to 100 µm
Number of cells in an organism	Usually unicellular	Can be unicellular or multicellular
Membrane-bound organelles	Absent	Present
Membrane-bound nucleus	Absent	Present

Thread of Curiosity: Why 'Prokaryotic' and 'Eukaryotic'?

Like the SI symbols met earlier in this series — *c* for celeritas, *g* for gravitas — biology, too, borrows heavily from Greek. ***Karyon*** is Greek for 'nucleus' or 'kernel.' ***Pro*** means 'before' or 'primitive'; ***eu*** means 'true.' So **prokaryotic**

literally means 'before a true nucleus,' and **eukaryotic** means 'true nucleus.' Bacteria, which evolved first and lack a membrane-bound nucleus, are prokaryotic. Plants, animals, fungi, and protists — all of which package their DNA inside a nuclear membrane — are eukaryotic.

Ready to Go Beyond: The Cytoskeleton and Cell Inclusions

In eukaryotic cells, a network of fine fibres called the **cytoskeleton** provides structural support, maintains cell shape, and enables movement and internal transport. It is visible only under an electron microscope. The cytoplasm may also store starch grains (in plant cells) or crystals of calcium oxalate or silica in some plant cells — these are known as **cell inclusions**.

2.3.1 Why Do Eukaryotic Cells Need These Organelles?

Eukaryotic cells carry out various life processes in different cell organelles, independently and simultaneously. Cell organelles help build new materials, remove waste, and provide energy to the cell — they work together to perform every function of the cell. In other words, **a cell is like a tiny living factory**, with each part doing a specific job.

Everyday Connection: A Cell Is Your Neighbourhood Delivery Company

Picture a food-delivery or e-commerce company's fulfilment centre. The **nucleus** is the head office, issuing instructions for everything that happens on the floor. The **endoplasmic reticulum** and **ribosomes** are the production line, manufacturing goods (proteins, lipids). The **Golgi apparatus** is the packaging and dispatch counter, wrapping and labelling items for delivery. The **mitochondria** are the backup generator room, converting fuel into usable power for every department. The **lysosomes** are the waste-management team, breaking down and recycling anything damaged or unwanted. No single department could run the company alone — and no single organelle could keep a cell alive alone either.

Nucleus — House of Coded Instructions

The nucleus has a double-layered covering called the **nuclear membrane**, which has pores that allow material to transfer between the nucleus and the cytoplasm. The **nucleolus** is a dense, round body inside the nucleus where ribosomal subunits are synthesised; these subunits then exit to the cytoplasm, where one large and one small subunit assemble to form a ribosome.

The nucleus contains **chromosomes**, visible as rod-shaped structures only when a cell is about to divide. Chromosomes carry information for the inheritance of characters from parents to the next generation, in the form of **DNA (Deoxyribonucleic Acid)** molecules. Chromosomes are composed of DNA and specific proteins; the functional segments of DNA are called **genes**. In a non-dividing cell, this same DNA exists as part of **chromatin** material — visible as an entangled mass of thread-like structures. Whenever a cell is about to divide, the chromatin organises itself into chromosomes.

Thread of Curiosity: The Cell That Gave Up Its Nucleus

Some cells are specialised to the point of giving up structures other cells depend on. Mature human **Red Blood Cells (RBCs)** have no nucleus (they are *enucleate*). The missing nucleus frees up space for more haemoglobin, letting each cell carry more oxygen to the rest of the body. But because they lack a nucleus, they cannot repair or divide themselves — so their lifespan is short, roughly **120 days**, after which they are broken down and replaced. Can you think of any other cells, in plants or animals, that function without a nucleus?

Prokaryotic cells do not have a well-defined nucleus. Their DNA exists as a single circular molecule associated with specific proteins, in a region called the **nucleoid**.

Ribosomes — The Protein Factories

Ribosomes are tiny structures, present either freely in the cytoplasm or attached to the endoplasmic reticulum. They are the sites of **protein synthesis**.

Endoplasmic Reticulum (ER) — Manufacturing Factory

The Endoplasmic Reticulum is a large organelle that spreads like a network within the cytoplasm, continuous with the outer membrane of the nuclear envelope. It plays a key role in synthesising and transporting proteins, fats (lipids), and some hormones in specialised cells. There are two types:

- **Rough Endoplasmic Reticulum (RER):** looks rough under an electron microscope because ribosomes are attached to its surface; mainly involved in protein synthesis and secretion (for example, in gland cells such as pancreatic cells).
- **Smooth Endoplasmic Reticulum (SER):** has no ribosomes on its surface, so looks smooth; involved in the synthesis and storage of fats and hormones.

Golgi Apparatus — The Packaging and Shipping Centre

Stacks of flattened, sac-like structures together form the **Golgi apparatus**. It is functionally linked to the ER, the cell membrane, and other organelles. The Golgi apparatus acts like the cell's post office — it modifies, sorts, and packages proteins and/or lipids into vesicles for transport, secretion, or lysosome formation.

Meet a Scientist: Camillo Golgi

The Golgi apparatus was first observed in 1898 by Italian scientist **Camillo Golgi**, in the nerve cells of a barn owl. Using special staining techniques, he saw a thread-like network — but the microscopes of his time could not resolve it clearly, so many doubted it was real. Decades later, electron microscope observations confirmed its existence, and it was named the 'Golgi apparatus' in his honour. Golgi went on to share the **1906 Nobel Prize in Physiology or Medicine** with Spanish neuroscientist Santiago Ramón y Cajal, for their work on the structure of the nervous system.

Lysosomes — The Clean-Up System

Cells produce waste materials and damaged, worn-out organelles during their activities. **Lysosomes** are single membrane-bound sacs filled with enzymes that can break down unwanted proteins, carbohydrates, fats, and even damaged parts of the cell, keeping it clean and healthy. The products of this breakdown are released into the cytoplasm, where they may be reused in other cellular processes.

🧵 Thread of Curiosity: Lysosomes at the Moment of Fertilisation

Human sperm cells contain lysosomal enzymes. When a sperm meets an egg, these enzymes help break down the outer layer of the egg, allowing fertilisation to take place. You will learn more about human reproductive cells later in Chapter 11.

🌍 Everyday Connection: The Cell's Waste Segregation Programme

Many Indian municipal corporations now require households to segregate wet and dry waste before collection, so recyclable and reusable material doesn't simply pile up. A lysosome runs a similar programme at the cellular level — breaking down damaged material and releasing usable components back into the cytoplasm for reuse, rather than letting waste accumulate and poison the cell.

Mitochondria — The Powerhouse of the Cell

Mitochondria are often called the 'powerhouses of the cell' because they supply the energy needed for most cellular activities. Each mitochondrion is surrounded by two membranes: the **outer membrane**, which is smooth and porous, and the **inner membrane**, which is folded into finger-like projections called **cristae** — folds that increase the surface area available for chemical reactions and energy production.

Inside mitochondria, glucose and other molecules are broken down to release energy during **cellular respiration**. This energy is stored in a molecule called **Adenosine Triphosphate (ATP)**, the cell's energy currency, used for most cellular activities.

🌍 Everyday Connection: Cristae and Your AC's Cooling Fins

Look at the back of a refrigerator or the outdoor unit of a split AC — you'll find tightly packed metal fins, folded again and again to pack the maximum possible surface area into a small space, maximising heat exchange. A mitochondrion's cristae solve the same engineering problem for chemical energy production: folding the inner membrane repeatedly packs far more surface area — and far more energy-releasing machinery — into the same tiny volume than a smooth membrane ever could.

Plastids — Centres for Food Synthesis in Plant Cells (and Beyond)

Animals obtain food from their surroundings, but plants synthesise their own food in the presence of sunlight, using special organelles called **plastids**. A green pigment called **chlorophyll**, present in the **chloroplast** (a type of plastid), absorbs sunlight for **photosynthesis**. Chloroplasts are double-

membrane-bound organelles, like mitochondria. Inside is a semi-fluid substance called the **stroma**, containing disc-shaped membrane structures that hold chlorophyll and absorb light energy during photosynthesis. The sugars produced are stored in the stroma, along with starch granules.

Mitochondria and plastids share a curious feature with certain bacteria: both have their own DNA and ribosomes, and can make some of their own proteins. These similarities are the basis of the widely accepted idea that mitochondria and chloroplasts share an evolutionary history with ancient single-celled organisms — a concept known as the **endosymbiotic theory**, which you will explore further in higher grades.

Not every plastid is green. **Chromoplasts** (from the Greek *chroma*, meaning colour) contain pigments other than chlorophyll — yellow, orange, or red — and are the source of bright colours in many flowers and fruits, helping attract pollinators and seed-dispersing animals. **Leucoplasts** (from the Greek *leukos*, meaning white) lack pigments altogether and store food such as starch, oils, or proteins — for example, the leucoplasts in potato and taro (arbi/Colocasia) cells store starch.

Everyday Connection: Watching Chromoplasts at Work on Your Kitchen Counter

Leave a green mango or a green tomato on the kitchen counter for a few days and watch it ripen. That shift from green to yellow, orange, or red isn't paint fading in — it is chloroplasts inside the fruit's cells actively converting into chromoplasts, swapping chlorophyll for other pigments. It's one of the few cell-biology processes you can watch unfold with your own eyes, without a microscope, over a single week.

Vacuoles — The Organelles for Storage and Support

In a mature plant cell, there is usually one large **central vacuole**, surrounded by a single selectively permeable membrane and filled with a watery fluid called **cell sap**. The vacuole stores water, minerals, sugars, and waste material, and by holding large amounts of water it maintains pressure inside the cell — keeping the plant cell firm. When a plant does not get enough water, the vacuole loses water, the cells become less firm, and the plant wilts. In animal cells, vacuoles are sometimes present, but are much smaller and used only for temporary storage.

Everyday Connection: The Tulsi Plant That Wilts by Afternoon

A tulsi or money-plant on an Indian balcony often looks limp and droopy by a hot afternoon, then perks back up within an hour of watering. That is the plant's vacuoles losing water pressure under heat stress, then refilling and restoring turgor once water is available again — a visible, everyday demonstration of a structure you cannot actually see.

Thread of Curiosity: Building a Cell From a Synthetic Genome

In 2010, scientist **J. Craig Venter** and his team made a landmark discovery in synthetic biology. They first read the complete DNA sequence of a simple bacterium, ***Mycoplasma mycoides***, using computer analysis, then chemically synthesised an exact copy of that DNA in the laboratory. Next, they took a

different, closely related bacterium, removed its own DNA, but kept the rest of the cell — its cytoplasm and cell membrane — intact, and inserted the synthetic DNA into it. The cell began to grow and divide, following instructions from the newly inserted synthetic DNA. This showed conclusively that **DNA controls the structure and activities of a cell**.

It's important to be precise about what this experiment did and didn't do: scientists did **not** create a completely new cell from scratch. Only the DNA was synthetic — every other part of the cell came from an already-living cell. This kind of research nonetheless underlies much of today's biotechnology industry, including India's own large biotech sector, which manufactures vaccines, insulin, and diagnostic kits used worldwide.

2.4 How Do Normal Cells Grow and Divide?

When you get a small cut on your skin, it heals within a few days. When hair falls out, new hair grows back. This happens because cells in your body can grow and divide to replace old, dead, or damaged cells. When your body grows, it isn't just because existing cells get bigger — cells can only grow up to a certain size. Growth happens because cells **divide** to form new cells.

Activity 2.5 — Redeveloped: Watching Onion Roots Divide

Everyday Version: Every Indian kitchen has a spare onion lying around — perfect for this activity.

- Fill a jar with plain water and rest an onion bulb over it so that its base — bearing roots — stays immersed.
- Leave the setup for 5–6 days. You should see fresh white roots growing downward.
- Cut 2–3 cm of the freshly grown root tips and transfer them to freshly prepared aceto-alcohol (glacial acetic acid : ethanol :: 1 : 3) for 24 hours, then move them to 70% ethanol for preservation.
- Wash a preserved root tip in water, place it on a clean slide, and add a drop of dilute Hydrochloric acid (HCl) for 10–15 minutes to soften the tissue; rinse, then add 2–3 drops of aceto-carmine stain.
- Leave the slide for 5–10 minutes, gently warm it (with caution) over a spirit lamp, then cut off the root tip, add a coverslip, and gently squash it with your thumb to spread the cells in a single layer.
- Observe the slide under a microscope.

What you'll see: the cells will not all look identical — they will show different structures corresponding to different stages of cell division, because the growing root tip divides continuously. This process is called **cell division**.

A parallel worth noticing: your fingernails and hair only 'grow' from their base (the nail matrix and hair follicle), not along their entire length — because that's where the actively dividing cells live, exactly like the growth zone at an onion's root tip.

Every day, an estimated hundreds of billions of cells in your body are replaced — almost 1 per cent of your body's total cell count. Both prokaryotic and eukaryotic cells divide, but eukaryotic cells divide in a more controlled and orderly manner,

through a process called the **cell cycle** (you will study its stages in higher grades).

2.4.1 Cell Division

Cell division is the process by which new cells are formed from pre-existing cells. It allows living organisms to grow, repair damaged tissues, and reproduce. Some cells, such as skin cells, divide continuously to replace cells lost regularly. There are two major types of cell division — **mitosis** and **meiosis**. Mitosis is important for normal growth, repair, maintenance, and asexual reproduction, while meiosis is important for sexual reproduction and the creation of genetic diversity.

Mitosis

Every human begins life as a single fertilised egg. This one cell divides repeatedly to eventually form trillions of cells in the body. Cells increase in number through **mitosis**, the most common type of cell division. Mitosis produces two genetically identical daughter cells from one parent cell — each new cell gets the same DNA and the same number of chromosomes as the parent cell, keeping genetic information largely consistent across all your body's cells.

Meiosis

Meiosis is a type of cell division that produces **gametes**, and it occurs only in the cells of reproductive organs. Gametes create variation and diversity among living organisms — which is exactly why children resemble their parents but are never identical to them. In animals (including humans), meiosis occurs only in the testes (producing sperm) and the ovaries (producing eggs). In plants, it occurs in the anthers (producing pollen) and the ovaries (producing egg cells).

In meiosis, the parent cell divides **twice**, one division after the other, to form **four** daughter cells. During the first division, the cell splits into two daughter cells, and the number of chromosomes in each is reduced to half. The second division resembles mitosis: each of those two daughter cells divides again, forming four daughter cells in total, each with half the parent cell's chromosome number. When gametes from two individuals combine during fertilisation, the original chromosome number is restored.

Meet a Scientist: Arun Kumar Sharma

Arun Kumar Sharma was a celebrated Indian botanist known for his work on chromosomes. He made major contributions to plant taxonomy, evolution, and development, and invented several useful laboratory methods still used to study chromosomes in plants today. For his contributions to botany, he received numerous honours, including the **Shanti Swarup Bhatnagar Award** and the **Padma Bhushan**.

Bridging Science and Society: Cell Culture and India's Tissue-Culture Industry

Scientists have developed methods to grow plant and animal cells outside the body, in special conditions — this is called **cell culture**. Cells are taken from an organism and placed in a nutrient-rich medium that allows them to grow and multiply, with the right temperature, acidity/alkalinity, moisture, and sterile conditions carefully maintained. Cell culture is crucial for studying how cells

work, and for producing biochemicals, food, medicines, and vaccines.

India has built one of the world's largest **tissue-culture plantlet industries** — producing enormous numbers of disease-free banana, sugarcane, and potato plantlets in sterile labs before they are transplanted onto farms. The fruit at your local vendor's cart may well have started life as a handful of cells multiplying in a lab dish. This industry rests directly on a concept called **totipotency** — the ability of a single plant cell to regenerate an entire plant — which you'll meet again in Section 2.5.

The processes of mitosis and meiosis must occur in a proper, controlled manner. **Errors in mitosis** can lead to uncontrolled cell division, resulting in tumours and an abnormal number of chromosomes in body cells. **Errors in meiosis** may result in genetic disorders associated with developmental problems or distinctive physical features, and can also cause early pregnancy loss or reduced fertility.

2.5 Cell Theory — The Unifying Principle of Biology

One of the most important observations about living organisms is that **all** organisms are made up of cells. In 1838, German botanist **Matthias Schleiden** reported that all plants are made up of cells. In 1839, German zoologist **Theodor Schwann** found that all animals are made up of cells too. Later, in 1855, German scientist **Rudolf Virchow** expanded the theory further, showing that new cells are formed only from pre-existing cells. Together, their work led to the formulation of the **Cell Theory**.

According to the classical Cell Theory:

- All living organisms are made up of one or more cells.
- The cell is the basic unit of structure and function in living beings.
- All cells arise from pre-existing cells.

This single theory unifies all of biology, from bacteria to humans, and explains life's continuity through cell division.

Meet a Scientist: Gottlieb Haberlandt and Totipotency

In 1902, Austrian botanist **Gottlieb Haberlandt** proposed that any living plant cell — even a fully mature cell from a permanent tissue — can develop into a complete plant if given suitable nutrients and favourable conditions. This special ability of plant cells is called **totipotency**. Haberlandt's idea laid the foundation for an entirely new branch of biology: Plant Tissue Culture Technology — the very same science behind India's banana and sugarcane tissue-culture industry mentioned in the previous section.

2.5.1 Do Cells Grow and Reproduce Forever?

Cells grow and divide in a controlled way, stay in the right place, carry out their functions, and eventually die when no longer needed. Dead cells are replaced by new cells carrying out the same function — every cell, in other words, has a **definite life span**. If cells fail to die on schedule, or die too early, problems arise in the body.

In many animal cells, division usually stops once a cell comes into contact with its neighbouring cells — a phenomenon called **contact inhibition**. Cancer cells lose this control and keep dividing uncontrollably, forming tumours. Plant cells, with their rigid cell walls, do not show contact inhibition and follow a different pattern of growth altogether.

Everyday Connection: The Cell That Never Stops at the Signal

Contact inhibition works a bit like a disciplined driver who stops the moment traffic ahead is dense enough — no pile-up results. A cancer cell is the driver who never reads the red signal: it keeps dividing regardless of how crowded its surroundings have become, and the result — like a chain of vehicles that never stop — is a tumour, a pile-up of cells where there shouldn't be one.

Thread of Curiosity: How Do Cancer Cells Grow and Spread?

Normal cells grow, age, and die in a controlled manner. Sometimes this control system breaks down, and abnormal cells start growing and dividing uncontrollably, forming tumours — which may be benign or malignant. Malignant (cancerous) tumours can invade nearby tissues and even spread to other parts of the body, forming new tumours elsewhere.

Ready to Go Beyond: Programmed Cell Death

Cells also have natural, built-in ways of dying, to maintain balance in the body. **Programmed Cell Death (PCD)** is a genetically regulated, organised process of selective cell destruction — essential for normal development, cellular quality control, and immune function. As a human embryo develops, PCD helps form individual fingers by deliberately eliminating the cells between what would otherwise be webbed digits. Without it, human hands would be webbed, like a duck's foot.

Even though cells are extremely tiny, they perform remarkable functions: producing energy, synthesising and secreting substances, dividing to form new cells, and working together to maintain the proper functioning of the entire body. Every living being, from a tiny bacterium to a giant tree, is made up of cells. You, too, are one of the products of these tiny, hardworking cells.

Chapter Summary

Concept	Core idea	Everyday example
Cell	Basic structural and functional unit of life	A single ***Lactobacillus*** turning milk into curd overnight
Microscope (light & electron)	Tools to see beyond the eye's 0.1 mm resolution limit	An onion peel viewed at 100X magnification in a school lab
Cell membrane & osmosis	Selectively permeable boundary; water moves toward the more concentrated solution	Salting raw mango (kairi) draws water out instantly

Concept	Core idea	Everyday example
Cell wall	Rigid outer covering (plants, fungi, bacteria) made of cellulose	Firm onion peel cells vs floppy cheek cells under a microscope
Prokaryotic vs eukaryotic cells	Presence or absence of a membrane-bound nucleus and organelles	Bacteria (no nucleus) vs your own cheek cells (with a nucleus)
Nucleus, chromatin, DNA	Houses genetic instructions as chromosomes and genes	Mature RBCs lack a nucleus, leaving more room for oxygen-carrying haemoglobin
ER, Golgi apparatus, ribosomes	The cell's manufacturing and packaging/shipping system	A factory's production line and dispatch counter
Lysosomes	Break down waste and damaged cell parts	A city's wet/dry waste segregation and recycling programme
Mitochondria	Release energy (ATP) via cellular respiration	Cristae folded like an AC unit's cooling fins, for maximum surface area
Plastids (chloroplast, chromoplast, leucoplast)	Food synthesis, colour, and starch storage in plants	A green mango turning orange-red as it ripens
Vacuole	Storage and turgor pressure/support	A wilted tulsi plant reviving within an hour of watering
Mitosis	Produces two genetically identical daughter cells	Skin healing after a small cut
Meiosis	Produces four daughter cells, each with half the chromosome number, for gametes	Why siblings resemble but never exactly match their parents
Cell Theory	All life is made of cells; cells arise only from pre-existing cells	Unifies bacteria, plants, and humans under one principle
Cell culture & totipotency	Growing whole plants or cell lines from single cells in the lab	India's tissue-cultured banana plantlet industry
Contact inhibition & cancer	Normal cells stop dividing on contact; cancer cells don't	A driver who never stops at a red signal, causing a pile-up (tumour)

Revise, Reflect, Refine — Exercises

Basic Recall

1. Differentiate between prokaryotic and eukaryotic cells using two features from Table 2.2, giving one real example of each.

2. Explain, in your own words, why a cell membrane is described as 'selectively permeable,' and name the specific process by which water crosses it.
3. State the three points of the classical Cell Theory, and name the three scientists whose work led to it.

Apply & Think

4. Two identical potato pieces are placed in Beaker A (plain water) and Beaker B (concentrated salt solution). Predict and explain, using osmosis, what happens to the weight of each piece after an hour.
5. A farmer named Deepa has a large surplus harvest of amla (Indian gooseberry) and lemons that she cannot sell fresh in time. She turns the excess into pickles, murabbas, and sharbat by adding measured amounts of salt, sugar, or jaggery, then stores them in glass bottles. (i) Which scientific concept from this chapter is she applying? (ii) How does a high concentration of salt or sugar prevent spoilage-causing bacteria and fungi from growing? (iii) Suggest one more traditional Indian food-preservation method that works on the same principle.
6. If all the mitochondria were removed from a eukaryotic cell, what would happen to the cell's ability to function? Justify your answer using what you know about cellular respiration and ATP.

Creative Design Challenges

7. **The Cell-as-a-Company Poster:** Design a labelled poster or infographic comparing a cell to any Indian company or service you use daily (a food-delivery app, a courier service, a bank). Assign each major organelle a 'department,' and justify every choice using its actual biological function.
8. **The Synthetic Cell Debate:** In 2010, J. Craig Venter's team built a bacterium containing fully synthetic DNA. Write a 150-word, balanced argument about one ethical question that a fully synthetic, lab-built cell — with both an artificial genome and artificial cell parts — might raise for society, referencing what you learned about DNA's role in controlling a cell's structure and activities.
9. **Build a Model:** Using low-cost, eco-friendly material (clay, waste cardboard, beads, wool, fruit peels), build a 3D working model of either a plant cell or an animal cell, clearly labelling at least eight organelles you learned about in this chapter.
10. **Nukkad Natak Script:** Write a short (1–2 minute) street-play script in which classmates role-play different organelles — nucleus, mitochondria, ribosome, Golgi apparatus, lysosome — explaining their job to a 'confused new cell' in simple dialogue.

Journey Beyond — Going Deeper

Challenge A: The Fermi Question — A Body's Worth of Replaced Cells

Recall the Fermi-estimation skill from Chapter 1. Your body replaces an estimated hundreds of billions of cells every single day — about 1% of its total cell count, out of a total human body estimated to contain roughly 30–37 trillion

cells. Estimate how many cells your body replaces over one full school year (about 200 school days, or all 365 days if you prefer). Show every assumption clearly, then research how many WhatsApp messages are sent across India in a year, and compare the scale of the two numbers. What does this comparison tell you about how differently we intuit biological scale versus digital scale?

Challenge B: Synthetic Biology and Its Questions

Research one real-world development in synthetic biology or cell-culture technology — lab-grown meat, tissue-cultured crops, mRNA vaccine manufacturing, or organ-on-a-chip research are all good starting points. Write a short reflection: which cellular concept from this chapter (osmosis, organelle function, totipotency, cell culture) underlies the technology you chose, and what is one ethical or societal question it raises for India specifically?

Challenge C: Design Your Own Osmosis Experiment

Design a simple, doable-at-home experiment to test whether the *concentration* of sugar syrup affects how fast a slice of raw mango (kairi) releases water through osmosis. Include: a clear hypothesis; your independent, dependent, and controlled variables; a step-by-step procedure you could actually carry out in your own kitchen; and a plan for recording and analysing your results.

Happy Exploring! Every cell in your body — and in the curd on your breakfast table — is proof that life's smallest unit is never simple. □□